2013 UK Fleet Optimisation Model
North Sea and West of Scotland demersal trawl segment

May 2006

Background

This model gives a snapshot look at fleet capacity and profitability in the year 2013. This report shows the results of a series of scenarios run on the model.

The model evolved from a basic model used by the Prime Minister's Strategy Unit (SU) team in their work to produce the Net Benefits report. Recommendation 4, relating to fleet size in the year 2013, fishing recovered stocks, is based on the model created by the SU team. This model was based on the idea that if a fishery is managed on a quota basis, then there is a total amount of revenue that can come from the fishery, there are costs incurred in catching the fish, and a total amount of profit from the fishery. If the average fishing vessel needs a certain amount of profit per year to be viable in the long term, then there is, in theory, a maximum number of vessels that can be profitable in the fishery.

The original SU model was made at a very outline level and was suitable for identifying problem areas within the fleet, where the number of vessels might significantly exceed the number expected to be profitable. The original model has been altered significantly to allow for more detailed costs of fishing, it has used improved price trend forecasts, and, importantly, it takes account of the fact that the total costs of catching the TACs will change if the number of vessels changes.

The total expected catch for each species in 2013 is taken from the SU model created by biologist David Agnew. This biological simulation model was used to generate the dynamic path of fish stock growth as a result of different management recovery assumptions. The proportion of total UK landings for each segment was based on official 2004 landings. The UK fleet was then separated into major segments and given its own model. This allowed us to change different parameters to allow the models to better reflect the fleet segments.

Context of using the model

This model can be used to run a range of different scenarios. This allows the user to better understand the relationship between a number of factors and the number of profitable vessels. As a result this model has a number of implications and can be used by government fisheries departments. The model essentially wants to maximise the number of vessels able to earn a given level of profit. However, due to some of the assumptions in the model restrictions will appear and these will need to be explained and discussed.

The North Sea and West of Scotland demersal trawler fleet

Within the North Sea (NS) and West of Scotland (WoS) demersal trawler fleet, two separate fleet segments can be defined, comprising of under 24 metre and over 24 metre vessels. The official SEERAD vessel descriptions for both fleets include demersal twin/multi trawl, demersal trawl, and demersal pair trawl.

The starting point for the analysis is based on the activity of the NS and WoS demersal trawler fleets in 2004, as follows:

Table 1: NS & WoS demersal trawler fleet landings in 2004

Fleet	No. of vessels	Total landings		Average landings	
		Tonnes	£	Tonnes	£
< 24m	155	34,388	45,058,582	222	290,700
> 24m	74	48,548	49,809,945	656	674,202

Table 2: Days at sea of the NS & WoS demersal trawler fleet in 2004

Fleet	No. of vessels	Average Days at sea	Minimum Days at sea	Maximum Days at sea	St. Dev. Days at Sea
< 24m	155	196	1	318	67.4
> 24m	74	252	16	358	71.6

Table 3: CPUE of the NS & WoS demersal trawler fleet in 2004

Fleet	No. of vessels	Average CPUE	Minimum CPUE	Maximum CPUE	St. Dev. CPUE
< 24m	155	1.10	0.00	4.05	0.60
> 24m	74	2.50	0.07	4.95	0.95

Vessels classified as an under 24 metre demersal trawler caught less than 50% nephrops (in volume terms) in 2004.

Clearly, from the above tables we can observe that some vessels in both segments had low activity levels in 2004, skewing the average landings, days at sea and CPUE figures. Without these vessels in the fleet, average activity and performance would be higher.

Using the model

The model is used by following the five steps on the Navigation Sheet to forecast the catch levels in 2013. To access each of the stages you click on the buttons on the right hand side of the Navigation Sheet and after each stage return to the Navigation Sheet again using the buttons. There is a separate model for both the over 24m and under 24m demersal fleet in the North Sea and West of Scotland. The user may not however change any values on both the forecast landings and revenue sheet and the prices sheet.

The model then forecasts three different scenarios for the fleet segment in 2013.

These are:

- Best Guess – This is the most likely scenario for stock progress (from the Agnew model) to 2013. The 2013 best guess prices have been estimated using the forecast trend from 2004-2013.
- Pessimistic – This is the lowest scenario for stock progress to 2013 and prices are set to be 10% less than the best guess estimate.
- Optimistic – This is the best scenario for stock progress to 2013 and prices are set to be 10% above the best guess estimate.

These three scenarios can be further differentiated by the user on the input page, if warranted, in terms of e.g. fuel price and CPUE.

The four steps of the model are as follows:

Step 1
In the first stage the user can view both the landings and revenues for the fleet along with prices. Landings and revenues for 2004 have been broken-down for each fish species. It then shows the values for all fleet segments in all areas and for the specific fleet segment the modelled under each of the three scenarios for 2013. It also gives you a breakdown of total landings and total revenues for each of the three scenarios. Revenues calculated are dependent on the prices shown in the price sheet. This prices sheet shows the price per tonne in 2004, the expected trend for 2004-2013 and the forecast prices for 2013. Forecast prices for 2013 under each of the three scenarios are also shown. The user is unable to change any values on these two sheets

Step 2
The second stage allows the user to change the input values. Here the user can change the minimum required level of average profitability per vessel in the fleet segment, the expected CPUE (tonnes of fish caught per vessel per day at sea), and the expected price per litre of fuel. Fuel price is an important factor within this model as this model assumes that any fuel price increase will not be passed onto the consumer in terms of higher fish prices. Therefore, fuel price will have a large impact on costs and as a result on the profitability of the fleet segment. Maximum days at sea per vessel can also be changed to represent the fleet under analysis only.

Step 3
When the user clicks on the Run Scenarios buttons, there should be a dialogue box with the message ‘Solver Found a Solution’, and asking you to click ‘OK’ to accept the solution found by the solver, for each of the three scenarios (pessimistic, best guess and optimistic). You should click ‘OK’ each time and then you will be returned to the Navigation Sheet. However if the message ‘Solver could not find a feasible solution’ appears then the user should click ‘OK’ but must note that the figures produced for that scenario are not viable as one or more of the constraints of the model, such as maximum days at sea, has been violated.

Step 4
To view the outputs the user must now click the Produce Report button on the Navigation Sheet. This gives the user a summary of the inputs and outputs from the calculations done in step 3. The user can then save these outputs to the summary sheet before running the model again with different input values. The summary sheet values can then be used to produce graphs etc, noting that a ‘no solution’ figure should not be reported or plotted.

Using the model

The Economic Model has been used here to answer several questions:

1. If all the 2004 fleet stayed active, what is the likely average level of operational profit they would have to work – and is this enough?
2. If a target average profit level was set, what level of fleet could be supported at this level of profit?
3. What sort of impact would increased catch efficiency have on the possible fleet size – in that being able to catch more fish with fewer days at sea would reduce a significant proportion of the operating costs?
4. What is the impact on the sustainable size of the fleet of changes in fuel costs without operators being able to pass any increase in costs on through to the sales price – i.e. costs increasing without revenue increasing?

1. Supporting the current fleet

The two segments of the NS and WoS fleet have different parameters. For the over 24m vessels in the NS and WoS we are assuming that the maximum days at sea are 310 and CPUE is 4 For the under 24m vessels in the NS and WoS we are assuming that the maximum days at sea are 250 and CPUE is 2. As the tabled results in Annex 1 suggest, the maximum days at sea constraint is not binding. The assumption that holds for both models is that the price of fuel is set at 25p per litre. Using the above assumptions the following levels of profit per annum will need to be achieved to support the current size of the fleet.

Table 4 – Profit levels to keep all current fleet viable

Fleet	Number of vessels in 2005	Pessimistic	Best Guess	Optimistic
< 24m	155	£32,750	£40,650	£45,500
>24m	74	£31,000	£50,000	£75,000

Table 4 shows us the profit levels that are required to keep the current fleet viable in 2013. Using the assumption that our ‘best guess’ scenario is the most likely situation in 2013, then we can see that the NS and WoS fleet must be operating at a profit level of between £40,000 and £50,000. However, this is under the assumption that the price of fuel will be 25p per litre, which given the current oil market is unlikely, as current prevailing prices are over 30p per litre. The assumed CPUE levels are also higher than currently observed on average. These issues will be considered later on in the report. The level of minimum profit also omits depreciation, interest payments on loans and the possibility of the vessel being out of action due to repairs.

2. Fleet sizes for given profit levels

The Strategy Unit stipulated that the level of operating profit required for those vessels that are left in the industry must cover investment, capital cost requirements and also be competitive. This level of inferred operating profitability required to invest and be competitive, was calculated partly as a result of reaching required return on capital in addition to consultation with industry actors. However the profit assumptions used by the SU in their modelling states that both NS and the WoS demersal seine sectors should both be operating at a profit level of £100,000 in 2013. However, no figures are offered for the trawling sector.

We believe that an acceptable profit level for the NS and WoS demersal fleet would be around £75,000 for over 24m vessels and £50,000 for under 24m vessels. These levels of profit allow the model to run within its constraints. The fuel price was set as being constant at 25p per litre and CPUE was set at 4 for the over 24m vessels and 2 for the under 24m vessels. Only the days at sea value is allowed to change to enable the model to maximise the number of vessels, within the constraints imposed. These base cases are tabulated in more detail in Annex 1.

Table 5 - Number of viable vessels at the benchmark profit levels

Fleet	Number of vessels in 2005	Target profit level	Number of vessels viable under each scenario:		
			Pessimistic	Best Guess	Optimistic
< 24m	155	£50,000	113	132	144
> 24m	74	£75,000	44	57	74

Table 5 shows the number of viable vessels at the benchmark profit levels. These figures show for the entire fleet that in the most optimistic scenario we would have a reduction of 11 vessels, in the worst case scenario we would see a reduction of 72 vessels, and in the most likely case we would see a reduction of 40 vessels.

The model was then run at different target levels of profit, from £30,000 per annum to £120,000. The charts in Annex 2 show the results of varying the target profit level of profitability of the fleet. For under 24m vessels there is no solution found for profit above £80,000 and for over 24m there is no solution found for profit above £120,000 under the current constraints. From these charts we can see where the model, and indeed fleet viability, starts to reach its limits. In the case of the under 24m the model starts to reach its limits when profit levels are above £120,000 in the most optimistic situation, above £80,000 in the worst case scenario and above £100,000 for the most likely scenario. We have a similar situation in the case of the over 24m model, which starts to reach its limits when profit levels are above £80,000 in both the most optimistic situation and the most likely scenario, and above £50,000 in the worst case scenario. These limits occur because of the parameters of the model. For example, the number of days at sea that the vessel may be required to fish to reach the profit level under the current constraints is over the maximum days at sea allowed.

3. Impact of changes in catch efficiency

In 2004 the average vessel CPUE was 2.5 for over 24m vessels and 1.1 for under 24m vessels. However our base case requires £75,000 and £50,000 minimum profits, and CPUE values of 4 and 2, for the over and under 24m segments respectively (see Annex 1). It is thus clear that the current fleet structure will need to change considerably to produce a situation of vessels with healthy profits. Furthermore, the model allows for vessels to spend 310 and 250 days at sea, respectively, which is again in excess of the average 2004 situation, see table 6 below.

Table 6 – Comparison of 2004 and best guess 2013 figures

Fleet	Average vessel CPUE		Average vessel days at sea		Average vessel profit	
	2004	Best guess	2004	Best guess	2005 forecast	2013 best guess forecast
< 24m	1.1	2.0	170	250	£9,000	£50,000
> 24m	2.5	4.0	250	310	-£9,000	£75,000

The model was then run at different CPUE levels, from 1.7 to 3.0 for the under 24m vessels and from 3.7 to 5.0 for the over 24m vessels. The charts in Annex 3 show the results of varying the CPUE levels whilst keeping fuel at 25p per litre and profit at £75,000 or £50,000 for the over 24m and under 24m sector respectively. Since the model is unable to give us solutions for lower CPUE levels currently observed, this is a constraint of the model. This is possibly due to actual number of days at sea required being greater than the maximum the model makes available to each vessel, resulting in profit levels below the required benchmark profit levels. No solutions are found below CPUE 1.7 for the under 24m segment, under any of the three scenarios. Similarly, for the over 24m vessels, no solutions are found below CPUE 3.7. Clearly, the pessimistic scenario finds the least number of feasible solutions, as shown in Annex 3.

Table 7 – CPUE levels to keep the entire fleet viable at the target profit levels

Fleet	Base line CPUE	CPUE under each scenario:		
		Pessimistic	Best Guess	Optimistic
< 24m	2.0	3.0	2.4	2.2
> 24m	4.0	5.5	4.6	4.1

Table 7 shows the CPUE levels required to keep the current fleet viable at the profit levels of £75,000 or £50,000 for the over 24m and under 24m sector respectively. It is clear that under the 2013 scenario, greater catches are anticipated and the vessels in the fleet need higher CPUE rates or days at sea to obtain those catches. However, the financial implications of spending extra days at sea, especially under scenarios of higher fuel prices, limit the opportunities to find feasible solutions. It is not always the maximum number of days (e.g. 250 days for under 24m vessels) that appears binding, but sometimes it is too costly to be out at sea to catch those extra catches, whilst still having a profit of £50,000.

Under the optimistic scenario for the over 24m fleet segment we require an increase from the entire fleet in catches, from the current 48,500 tonnes to 66,000 tonnes in 2013. For the under 24m segment the increase needed is from 34,000 tonnes to almost 50,000 tonnes. This required increase in catches (i.e. the model works on the assumption that all possible catches are caught), needs a change in CPUE, total days at sea or change in vessel number. Currently, large vessels need to work approximately 300 days per year to be profitable (at current CPUE rates). But, on a recovered stock, the same number of vessels might fish fewer days, but still get the same volume. Therefore, they will get, same revenue at lower cost, and hence, more profit on fewer days. This is generally because of the greater expected density of fish on the grounds and consequently higher catch rates (CPUE).

Although higher CPUE may be restricted by the physical holding capacity of a vessel on a trip basis, it is expected that vessels will simply land more frequently. However, it is noted that this will increase costs incurred from extra steaming time and decrease the amount of time available for fishing (if days at sea restrictions are still an influential limiting factor). A further possibility is the influx of more vessels that can catch the extra catch, and so mitigating the need for improvements in CPUE of the current vessels. However, the financial implications in terms of new capital entering the segment ought to be considered. Currently, the model only considers the operating costs (fishing and vessel owner expenses) and revenues, i.e. net profits. As shown in some of the trial runs, certain scenarios do allow for an increase in fleet size.

It is not expected that changes in quota or days at sea restrictions will have an impact on CPUE, as it is presumed that when the vessel is at sea it will try to catch as much as possible. Changes in gear restrictions could, however, and need to be considered in the longer term. We assume that under current management vessels try to catch their catch in the shortest time possible. If the management (quota) regime does not change, then this behaviour can also be anticipated to continue.

4. Impact of an increase in the price of fuel

The price of fuel is a vital consideration when assessing the future profitability of the NS and WoS demersal fleet. Currently the price of fuel is around 32p per litre excluding duty. The way that fish are sold contributes to the problems of passing increasing costs onto consumers, where fish are sold at auction and the buyers set the price. As a result the fishermen have little control over the price that their fish sells for, and are thus unable to pass extra fuel (production) costs onto the consumer in the short term.

Table 8 – Implications of changing the price of fuel on the best guess size of the fleet in 2013

Profit level/ segment	£50,000 / < 24m	£75,000 / > 24m
Fuel Price		
£0.14	153	82
£0.16	149	78
£0.18	146	73
£0.20	142	69
£0.22	138	64
£0.24	134	60
£0.26	130	55
£0.28	127	51
£0.30	123	46
£0.32	119	No solution
£0.34	115	No solution

Table 8 shows how the best guess scenario for the size of the fleet changes as fuel price increases. We can see that increasing fuel costs has a greater effect on the fleet size of the over 24m vessels than the under 24m vessels. This is generally due to the higher fuel dependency of the larger vessels. The over 24m vessels also have a longer steaming time to get to their fishing grounds, increasing the volume of fuel used on an average trip. This increase in fuel cost has clear financial implications as currently the over 24m vessels are unable to offset these extra costs by direct improvements in revenues. The under 24m vessels in contrast seem less vulnerable. No feasible solution is found for the over 24m vessels when fuel price per litre is over 30p, for under 24m vessels no feasible solution is found when the fuel price is over 40p per litre, using the best guess scenario. This situation has been repeated for all three scenarios and is charted in Annex 4.

Analysing the sensitivity of the model

The issue of the sensitivity of the model to key parameters has been further examined. We looked at both the sensitivity of the model with respect to CPUE, keeping fuel at 25 pence per litre, and the sensitivity of the model when we look at the CPUE level required to enable the entire current fleet to still be viable in 2013 at the current fuel price (32 pence). The results are shown in tables 9 and 10 respectively.

Table 9 – Minimum CPUE required to obtain a solution when fuel price is £0.25

Fleet	Base line CPUE	CPUE under each scenario					
		Pessimistic		Best Guess		Optimistic	
		CPUE	Number of vessels	CPUE	Number of vessels	CPUE	Number of vessels
<24m	2.0	1.76	95	1.69	105	1.69	112
>24m	4.0	3.94	43	3.72	48	3.62	56

In table 9 we examine the CPUE required for the model to give us a solution under each scenario at a fuel price of 25p per litre. We analysed the CPUE down to two decimal places and changed the CPUE level at intervals of 0.01. Number of vessels was also given to show how the size of the fleet varies.

Table 10 highlights the CPUE and number of vessels required to maintain a profit of £50,000 or £75,000 for the under 24m vessels and over 24m vessels respectively. Two objectives were then looked at, the first being the minimum CPUE required for the model to produce a solution and the second assessing the CPUE required to keep the current fleet size. The CPUE was again evaluated to two decimal places in order to asses the sensitivity of the model.

When looking at the sensitivity of the model we examined what would happen to the CPUE if we changed the fuel price from 25p to 32p per litre. Comparing the data in tables 9 and 10 we found that in the best guess scenario, the under 24m vessels were less sensitive to this fuel price change than the over 24m vessels. We found that the model required different minimum CPUE levels to be able to produce a solution. To get a solution when fuel increased from 25p to 32p per litre, CPUE rose by only 0.09 for the under 24m vessels, and reduced the number of viable vessels by 6. For the over 24m vessels, CPUE had to rise by 0.35 and the fleet reduced by 4 vessels.

Table 10 - Model sensitivity with respect to fuel at £0.32

Fleet	Objective	2013 Scenarios					
		Pessimistic		Best Guess		Optimistic	
		CPUE	Number of vessels	CPUE	Number of vessels	CPUE	Number of vessels
<24m	Minimum CPUE to get a solution	1.87	90	1.78	99	1.78	106
	Keep current fleet size	3.32	155	2.56	155	2.31	155
>24m	Minimum CPUE to get a solution	4.33	39	4.07	44	3.90	51
	Keep current fleet size	6.25	74	5.16	74	4.43	74

If we compare these results to table 7 we can also see the difference in the CPUE level required to enable the entire fleet to remain viable in 2013, when there is an increase in the price of fuel. In the best guess scenario for the under 24m and over 24m vessels, we require a CPUE rise of 0.16 and 0.56 respectively.

Comments from peer review

An external peer review was undertaken by Dr Simon Mardle of Cemare, University of Portsmouth. His full report can be found in Annex 5. He outlines a range of operational issues that should be considered to improve the usefulness of the model, some of which have been subsequently given extra attention in the model runs and reporting. In particular, further sensitivity analysis with smaller changes in CPUE and imposing current fuel prices has been carried out. The report also suggests a number of possible adaptations and extensions to the model, including:

- Disaggregating CPUE for the most targeted species (this approach has been applied in the modelling of the Northern Ireland fleet segments,

undertaken by Diana Tingley). Such an approach will give the model increased flexibility.
- From a technical point of view, it may be easier to find optimal solutions if we impose linear rather than non-linear assumptions. To test this we can fix the number of days at sea per vessel and only allow the number of vessels to vary.
- The model is flexible, in that we can ask to change the management objectives. Currently we are seeking the maximum number of vessels earning a certain profit, but we can similarly ask the model to maximise yield or employment in the fishery.

The current model report does not apply these suggestions, but they could be considered in future work.

The report further acknowledges that the model does not consider the dynamics of getting from the current situation to 2013. For example, it does not look into the required changes in effort levels over time that will allow the fishery to reach the 2013 Agnew catch predictions. Since this dynamic path will have structural and financial implications for the fleet, and impact the likely development of the fish stocks, such changes could be investigated further. Further, the model does not consider the best way of getting from the current fleet size to the optimal situation (for fleet, community or stocks). For current purposes, however, the model does provide a practical tool designed to evaluate the size of a given fleet in the medium term, and offers static solutions only.

Conclusions

The model offers a practical tool to assess the size of an optimal fleet, given a set of assumptions and model inputs. The user needs to be aware of these assumptions and model inputs to ensure that results are properly interpreted and qualified. The results from the model are only indicative as there are many uncertainties (e.g. fuel prices, stock recovery). Hence the 2013 vessel numbers reported in tables and figures should only be used to flag areas of management concern.

Four management questions have been considered for the NS and WoS demersal trawl fleets (see page 3), given a set of base case inputs and assumptions (e.g. fuel price of 25p). For the best guess scenario we find that:

The under 24m vessels can earn an average of £40,650 per vessel in 2013, if they want to remain at the current fleet size (155). Only 132 vessels should remain if we impose a minimum profit level of £50,000. To maintain 155 vessels viable at £50,000 profit levels, we require an average CPUE of 2.4 (compared to 1.1 currently observed). Applying a fuel price as currently observed (32p), suggests that only 119 vessels are viable.

The over 24m vessels can earn an average of £50,000 per vessel in 2013, if they want to remain at the current fleet size (74). Only 52 vessels should remain if we impose a minimum profit level of £75,000. To maintain 74 vessels viable at £75,000 profit levels, we require an average CPUE of 4.6 (in contrast to the current average of 2.5). Applying a fuel price as currently observed (32p), gives no optimal solution, expressing the extra vulnerability of the larger vessels to rising fuel prices.

More insight is gained into optimal fleet sizes under pessimistic and optimistic scenarios, currently qualified in terms of stock recovery and fish prices. The scenarios can be further differentiated by applying different fuel prices and CPUE rates, for example.

The peer review highlights the merits of the model and outlines a range of suggestions (e.g. disaggregated CPUE) that could improve the flexibility of the model, increasing the scope for providing management advice. Of particular note:

- The model results are static and do not consider the dynamic path (economic and biological) of getting from the current situation to an optimal 2013 situation.
- The model does not fully explain all possible fleet scenarios. For example, the levels of CPUE and fuel prices imposed for the over 24m vessels in particular does not describe the current situation, but are needed to make the model run the various scenarios. Further sensitivity runs have been carried out to investigate the robustness of the model in this respect.
- The model can be adapted to consider other management aims (e.g. employment maximisation) and can potentially be extended to investigate dynamic aspects of fleet development in future work.

The current model is set up to reflect the NS and WoS demersal trawl fleets. Similar work can be extended to other UK fleet segments, where catch and costs and earnings data are available. The model framework has already been adapted to the beam trawl segment in the Channel and South West, and to whitefish and nephrops trawlers in Northern Ireland (separate reports for this work have been produced).

Erik Lindebo
Hazel Curtis
Susan Anton

Annex 1: Base cases for <24m and >24m NS & WoS demersal trawlers

NS & WoS <24m Demersal trawl

Name of fleet segment:	**Under 24 m North Sea and WoS**		
Current (2005) no. of vessels:	**155**		

Scenarios	**Pessimistic**	**Best Guess**	**Optimistic**
Required minimum profit per boat:	**£50,000**	**£50,000**	**£50,000**
Fuel price:	**£0.25**	**£0.25**	**£0.25**
Max days at sea set to:	**250**	**250**	**250**
CPUE (avg tonnes per day) set to:	**2.0**	**2.0**	**2.0**

Scenarios	**Pessimistic**	**Best Guess**	**Optimistic**
Total segment revenues	**£43,685,136**	**£50,685,476**	**£57,423,400**
Total segment catch (tonnes)	**41,812**	**43,565**	**46,858**
Expected catch: avg tonnes per day per boat	**2.0**	**2.0**	**2.0**

Number of profitable vessels:	**113**	**132**	**144**
Tonnes per year per vessel	370	329	326
Days per year for whole segment	20,906	21,782	23,429

Data per vessel	**Pessimistic**	**Best Guess**	**Optimistic**
Total earnings (average per vessel)	**£386,832**	**£383,166**	**£399,348**
Crew share	£122,729	£124,003	£130,173
Total fishing expenses	£264,103	£259,162	£269,176
Total vessel owner expenses	£72,729	£74,003	£80,173
Total expenses	£336,832	£333,166	£349,348
Days at Sea per vessel	**185**	**165**	**163**
Actual profit level per vessel	**£50,000**	**£50,000**	**£50,000**

NS & WoS >24m Demersal trawl

Name of fleet segment:	**Over 24 m North Sea and WoS**
Current (2005) no. of vessels:	**74**

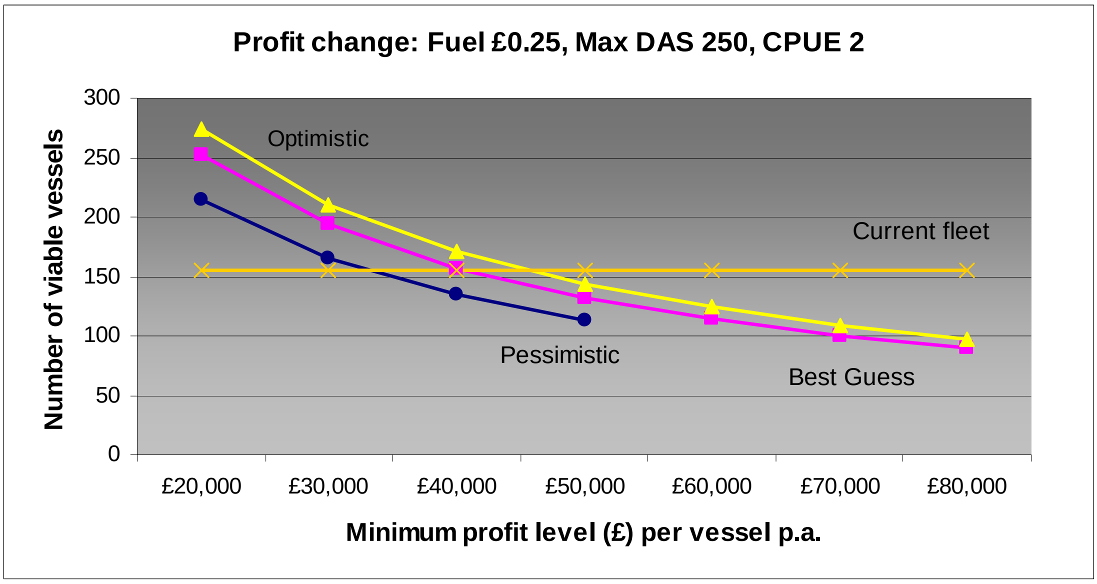
Scenarios	**Pessimistic**	**Best Guess**	**Optimistic**
Required minimum profit per boat:	**£75,000**	**£75,000**	**£75,000**
Fuel price:	**£0.25**	**£0.25**	**£0.25**
Max days at sea set to:	**310**	**310**	**310**
CPUE (avg tonnes per day) set to:	**4.0**	**4.0**	**4.0**

Scenarios	**Pessimistic**	**Best Guess**	**Optimistic**
Total segment revenues	**£42,773,261**	**£51,704,007**	**£67,458,756**
Total segment catch (tonnes)	**52,037**	**55,199**	**62,066**
Expected catch: avg tonnes per day per boat	**4.0**	**4.0**	**4.0**
Number of profitable vessels:	**44**	**57**	**74**
Tonnes per year per vessel	1,173	961	841
Days per year for whole segment	13,009	13,800	15,516

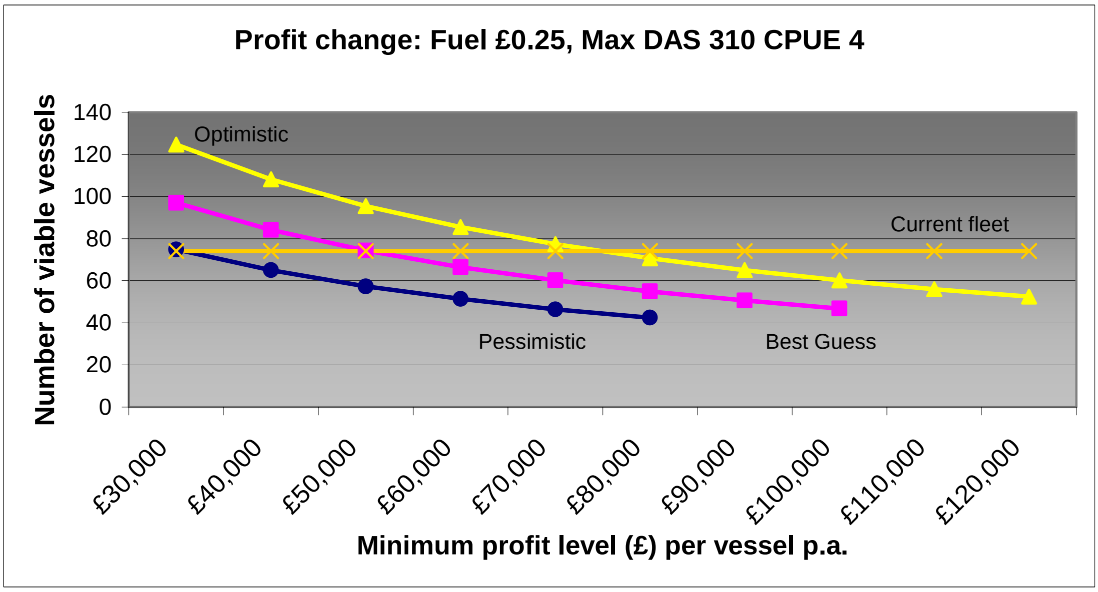
Data per vessel	**Pessimistic**	**Best Guess**	**Optimistic**
Total earnings (average per vessel)	**£964,553**	**£899,794**	**£914,189**
Crew share	£277,106	£273,092	£291,552
Total fishing expenses	£687,448	£626,702	£622,637
Total vessel owner expenses	£202,106	£198,092	£216,552
Total expenses	£889,553	£824,794	£839,189
Days at Sea per vessel	**293**	**240**	**210**
Actual profit level per vessel	**£75,000**	**£75,000**	**£75,000**

Annex 2: Viable fleet sizes for varying levels of fleet profitability

NS & WoS < 24m Demersal Trawl

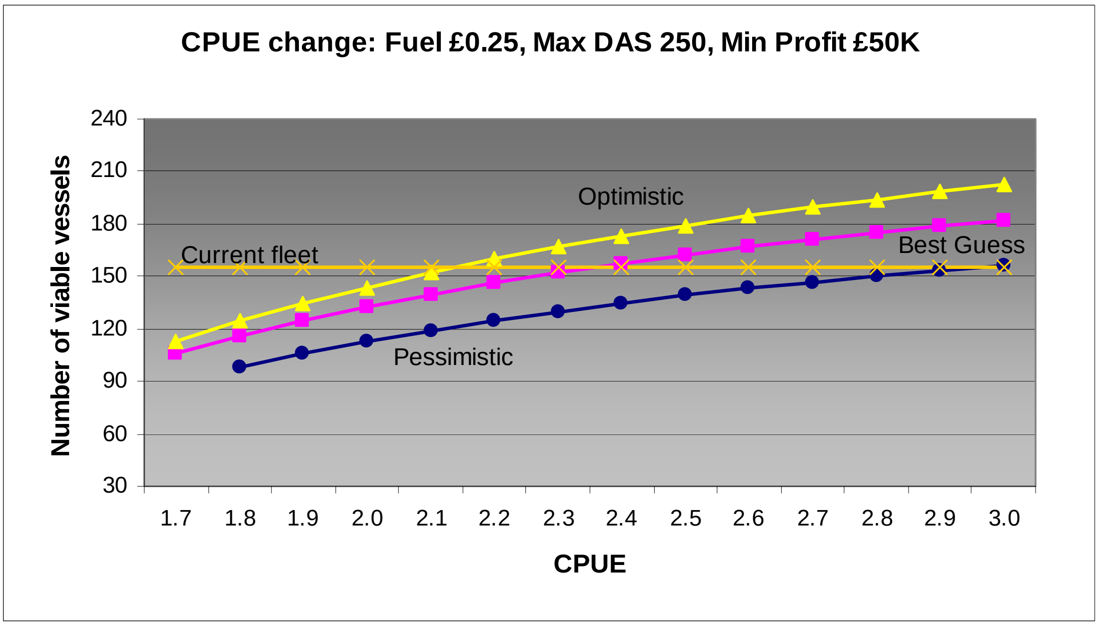


NS &WoS >24m Demersal Trawl

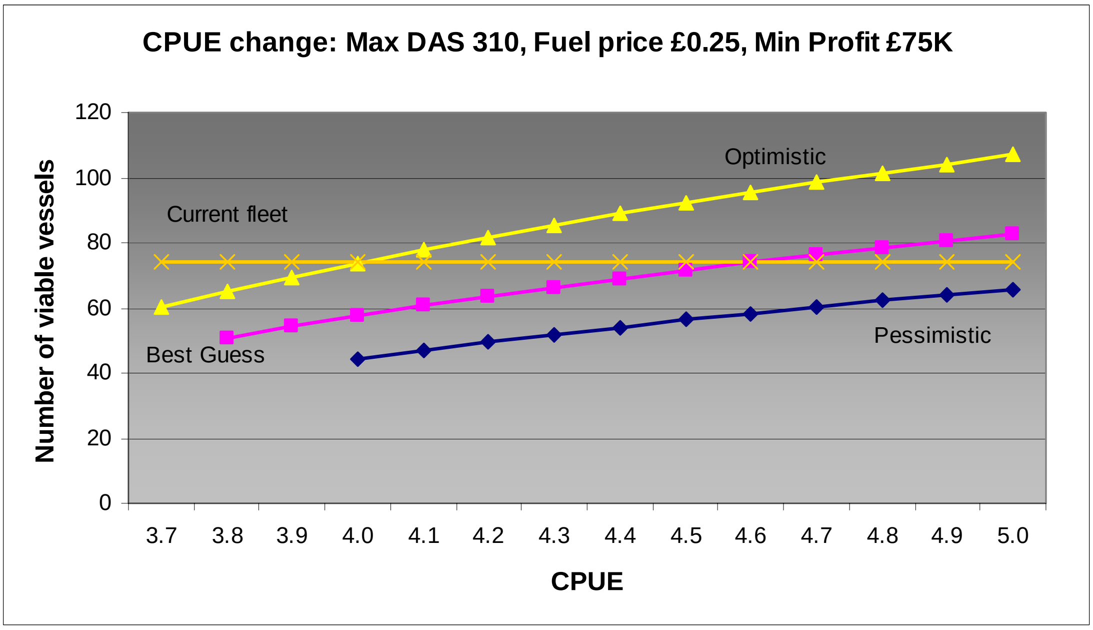


Annex 3: Impact of changing CPUE

NS & WoS < 24m Demersal Trawl

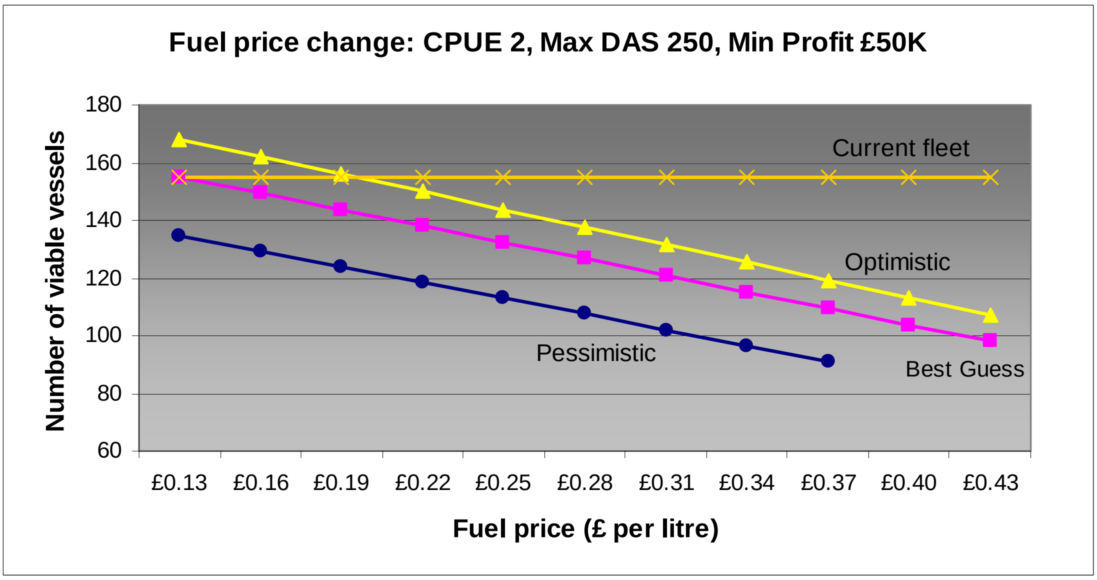


NS & WoS > 24m Demersal Trawl

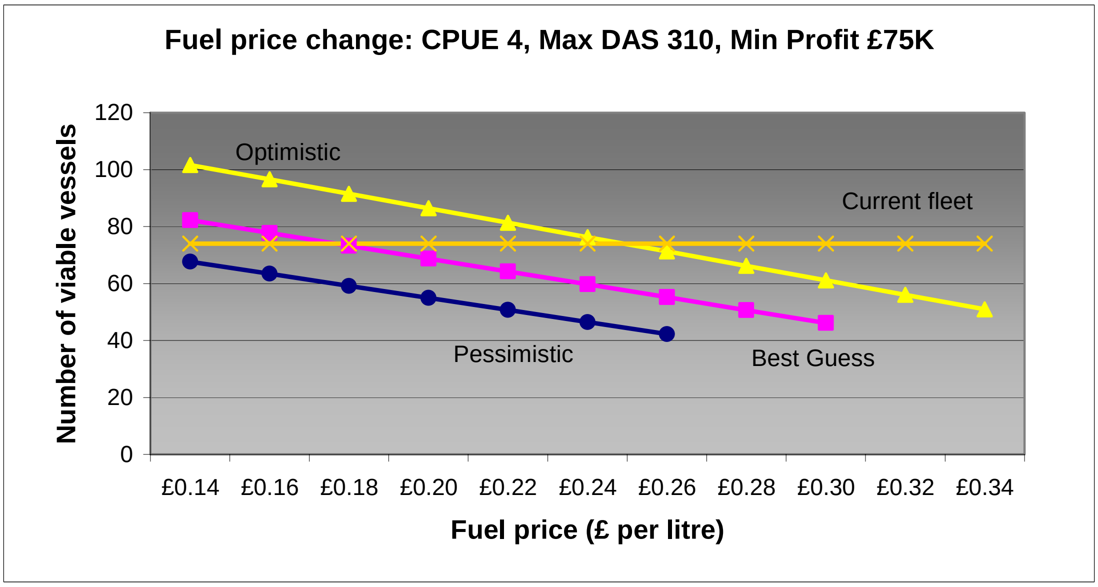


Annex 4: Impact of changing the level of fuel prices

NS & WoS < 24m Demersal Trawl



NS & WoS > 24m Demersal Trawl



Annex 5: Review of SFIA's 2013 Fleet Optimisation Model

Simon Mardle (October 2005)

CEMARE, University of Portsmouth, Boathouse 6, College Rd, H.M. Naval Base, Portsmouth, PO1 3LJ.

The implemented model

The model that is developed is designed to capture information that relates to the size of a specific fishing fleet[1] given limitations of stock availability for the period to 2013. The Prime Minister's Strategy Unit (SU) provided estimates of total allowable catch (TAC) for this period from which estimates of revenue are calculated (10 TAC species as well as 28 non-quota species). It is essentially a short-run approach to evaluate how many vessels can exist in the fleet in 2013 with acceptable profitability levels and without exceeding the estimated TAC. Current (i.e. 2004) proportions of fleet TAC are assumed throughout the period.

The stated model objective is to minimise super-normal profit of the fleet, allowing the number of boats and days fished to change in order to optimise the situation. This is done by maximising the number of vessels in the fleet. Essentially, this ensures that the average vessel makes an acceptable yearly profit. Three scenarios are modelled: pessimistic, best guess and optimistic. These are differentiated given different levels of predicted catch as given by the SU. In the base case, the cost of fuel per litre is constant (25 pence/litre) over all scenarios, although it may be changed for further scenario analysis.

The catch of a vessel is determined through an average catch per unit effort, CPUE, (i.e. tonnes per day). It is understood that this has been estimated using observed catches for the fleet and validated by a number of fleet representatives. This variable has a strong influence in the model and may be influenced by logbooks and subjective expert advice.

The data used for costs and earnings is highly detailed at the average vessel level and relates directly to the new European data regulations concerning economic data collection for fishing fleets. This makes the structure of the model highly transferable. The model uses total revenues and total costs of the fleet to evaluate the problem ultimately.

An immediate technical observation is that in order to adjust the number of vessels and the days fished per vessel, to achieve a minimised super-normal profit, the rigid framework (i.e. no adjustment or flexibility in other parameters) may not realise an optimal solution in all instances. This may have some implication for the interpretation of results and is discussed further below.

The model is developed in an MS Excel spreadsheet and uses the Solver tool for estimation of results. This makes it widely accessible, but in my opinion it should only be used by those closely involved in the development of the model. It would be very easy to produce very biased (and unrealistic) results from such a free-form model. The structure of the model makes good sense for an immediate coarse estimation of the likely size of the fleet in the medium-term.

---

[1] In the model reviewed, data related to the fleet of over 24m vessels that fish in the North Sea and West of Scotland.

For a given fleet segment per year, the defined model as presented can be written as:

Maximise ***total_vessels***

subject to,

average_vessel_days ≤ *Max_vessel_days* (set to 310 days)

actual_segment_profit ≤ 500 (in £s)

total_vessels * ***average_vessel_days*** = *Total_landed_catch / Average_CPUE*

vessel_profit ≥ *Acceptable_vessel_profit* (set to £50,000)

where *actual_segment_profit* is the revenue of the fleet segment estimated using the expected catch predictions minus the total costs of the fleet segment adjusted by number of vessels and days fished. Similarly, *vessel_profit* is the estimated average profit per vessel given the adjusted number of vessels and days fished. Note that variables in bold are allowed to vary in the model to achieve an optimal situation. Also, constraint 2 is particularly restrictive – if I am correct this constrains each vessel to be within a range of less than £500 for its annual profit.

A critique of the model

Given the construction of the model, there are several observations that can be made:

- The model offers a static solution – that is the situation that is likely to exist in 2013 given scenarios of pessimistic, best guess or optimistic catch. As such it gives an indication *now* as to what size the fleet could be as well as the activity of that fleet in 2013. There is clear need for such an immediate result as, if the fleet cannot make acceptable profits in the medium-term (i.e. by 2013), then an indication as to the catching capacity of that fleet must be evaluated to instigate management measures at the present time.
- The model is not dynamic, giving an indication of the flow of profits over time and accordingly the number of vessels over time. This is not an aim of the model and is not necessarily a criticism, however it is an assumption that must be made clear in the interpretation of results. The model presents the situation as estimated in 2013 only.
- It is not clear how the catch predictions are prepared and as such what levels of effort are assumed by the fleet over time to make the catch predicted in 2013. Does the optimal fleet effort level given by the model relate to that used by the SU in predicting catch? This is not clear. It would have major implications on the results if for example a fleet was not allowed to fish in certain areas over the period 2005-2013.
- Related to the previous observations, there is no link in the model that relates the current number of vessels in the fleet to the optimal level estimated for 2013. If a reduction in vessels is estimated (as in the case study evaluated), then when should this reduction be made to achieve the best results for the fleet or community or management of the stock? This is not necessarily an aim of the model to provide this information. However, this would have implications on the stocks, but it is a limitation of the model. Assumptions as to ‘how’ this is done would certainly be out of the scope of the model.
- An average CPUE for the fleet is used for all species targeted. It is not necessarily a criticism, but in making the CPUE of key target species for the fleet explicit may give the model more flexibility and more accuracy. This would remove the effect of averaging across all species for the economically important species to the fleet (e.g. cod, haddock, saithe and whiting for the case study fleet). As a note, the same CPUE is used across scenarios, however this could be expected to

differ significantly from the pessimistic stock situation to the optimistic one. Reasons for this could be commented on.

- Uncertainty of model results is not addressed in the version evaluated. This is not a weakness in the model developed, but a weakness in the use of the model, as the model is deterministic. This can be (and I assume is) easily overcome through some sensitivity analysis. This is talked about only briefly in the accompanying report.
- Given the estimation of an optimal fleet in the medium term, the model assumes consistency in the catch composition, activity of the vessels and in the cost structure of the vessels. Given the previous observation, producing a stochastic analysis would give an indication as to the uncertainty surrounding the sensitivity of the model to these two factors.
- It is noticeable that, in the case study reviewed, a very low fuel price is used (25p/litre). In my opinion this is unrealistic at this point in time. Current fuel price is 30-35p/litre and there are few macro-economic predictions that suggest fuel prices will decrease in the short to medium term. This will affect the results considerably as a high percentage of the total costs of the case study fleet is related to fuel. The sensitivity of the model results to fuel price should be investigated and reported using the current price as a base.

Some technical observations that can be made are:

- I would advise against reporting on any solution from a linear or non-linear optimisation model that is not optimal. Technically, this would invalidate any solution produced. The highly constrained nature of the presented model makes it highly likely not to be optimal. Checks should be made to ensure optimality.
- The model is non-linear. This is simply due to the fact that the variables *total_vessels* and *average_vessel_days* are multiplied together. This makes solution and verification that the solution is optimal considerably more difficult than if the model was linear. A simple linearisation might be to make *average_vessel_days* constant and run the model for this variable between a range of values. MS Excel Solver could then be used in a linear form.
- More flexibility could be incorporated in the model by allowing some variables to vary between bounds. Such variables include: CPUE (possibly in a more disaggregated form as discussed above) and crew share.
- The “assume non-negativity” condition of Solver should be checked to restrict solution search to positive values only. Both vessels and days must be positive. This assists solution and applies to linear and non-linear versions.
- The sensitivity of the model to small changes in key parameter values (in particular CPUE) should be evaluated and reported. The results should be interpreted in this context, where robustness in results is assured given reasonable tolerances.

Some theoretical observations that can be made are:

- The model developed is clear and practical. It can be viewed as a tool that can be used for a fast response to the question, what might the size of the fleet be in 2013 given the predicted stock situation? It provides an indicative analysis at the overall fleet segment level. This is particularly useful for managers. It is not an academic question. As such it is not designed to provide a theoretically validated and/or detailed analysis.
- The model is a static view of the situation in the medium term. It does not include aspects of investment and change in prices/costs over time. Therefore, there is a high level of theoretical uncertainty to the model. However, this does not detract from the practicality of the model in the management setting for which it is developed.

- The model does not provide solutions that relate to a long-run equilibrium and, as noted previously, it is not dynamic either. Therefore, the model is not theoretical (that is, being designed and developed directly from fisheries economics theory), but it is a practical implementation to consider one specific question about the size of the fleet in the 'near future'. I do not see this a major issue given the use of the model.
- It may be that further questions could be answered using this approach, by simply modifying the objective under analysis. In this case it is maximising fleet size, but it could just as easily be maximising yield or employment for example.

Summary

The model implemented is a practical tool designed to evaluate the size of a given fleet in the medium-term. It could be shown to be a useful tool in the development of management measures. It contains many assumptions, but as far as I can see it offers a fair indication of the possible situation given pre-determined stock conditions. This could be particularly constructive in the comparison of the size of the current fleet and that estimated to be optimal in the near future. I would advise that advice produced in using the model be suitably qualified with respect to uncertainty in the data and model, and to sensitivity in the model.

Annex 6: Seafish response to CEMARE Review

Seafish Economics are pleased that Simon Mardle agreed to review the model and gave such thorough comments on its design and use. We are pleased with his assessment and agree with most of the points raised. However, there are some points which we still aim to talk over with him to explore possibilities for improving the model.

The CEMARE comments and the Seafish responses are outlined below.

CEMARE comment	***Seafish Response***
The model is not dynamic, giving an indication of the flow of profits over time and accordingly the number of vessels over time. This is not an aim of the model and is not necessarily a criticism, however it is an assumption that must be made clear in the interpretation of results. The model presents the situation as estimated in 2013 only.	*We agree with this comment. This has now been clarified at the top of the report and will always be emphasised in presentations or discussions concerning the use of this model*
It is not clear how the catch predictions are prepared and as such what levels of effort are assumed by the fleet over time to make the catch predicted in 2013. Does the optimal fleet effort level given by the model relate to that used by the SU in predicting catch?	*The optimal fleet effort level given by the model does not relate to that used by the SU in predicting catch and this will be made more explicit in the report. Our catch predictions are based on the work by David Agnew and we are satisfied with this.*
There is no link in the model that relates the current number of vessels in the fleet to the optimal level estimated for 2013. If a reduction in vessels is estimated (as in the case study evaluated), then when should this reduction be made to achieve the best results for the fleet or community or management of the stock? This is not necessarily an aim of the model to provide this information. However, this would have implications on the stocks, but it is a limitation of the model. Assumptions as to 'how' this is done would certainly be out of the scope of the model.	*We agree that this should be made more explicit in the report. However, we agree that it is beyond the scope of the model to account for this.*
An average CPUE for the fleet is used for all species targeted. It is not necessarily a criticism, but in making the CPUE of key target species for the fleet explicit may give the model more flexibility and more accuracy.	*We agree that this is a good idea, however we do not think that the extra work would improve the quality of the debate and this is the main purpose of the model. This could be explored further if the profitability group feel it is an important aspect to address.*
Uncertainty of model results is not addressed in the version evaluated. This is not a weakness in the model developed, but a weakness in the use of the model, as the model is deterministic. This can be (and I assume is) easily overcome through some sensitivity analysis. This is talked about only briefly in the accompanying report.	*We agree with this comment. This issue has already been expanded upon in the report. More in depth discussions on sensitivity analysis could also be carried out if the profitability group feels it is important.*

Given the estimation of an optimal fleet in the medium term, the model assumes consistency in the catch composition, activity of the vessels and in the cost structure of the vessels. Given the previous observation, producing a stochastic analysis would give an indication as to the uncertainty surrounding the sensitivity of the model to these two factors.	*We feel that this issue should be explored further. Simon Mardle will be consulted on this issue.*
In the case study reviewed, a very low fuel price is used (25p/litre). In my opinion this is unrealistic at this point in time. Current fuel price is 30-35p/litre and there are few macro-economic predictions that suggest fuel prices will decrease in the short to medium term.	*We agree. We are planning on raising the price of fuel to 30p per litre in our base case scenario.*
The sensitivity of the model results to fuel price should be investigated and reported using the current price as a base.	*We agree. This has been addressed in the current report. This will be updated to reflect the new base fuel price and could also be examined for all three scenarios if requested.*
I would advise against reporting on any solution from a linear or non-linear optimisation model that is not optimal. Technically, this would invalidate any solution produced. The highly constrained nature of the presented model makes it highly likely not to be optimal. Checks should be made to ensure optimality.	*We agree. Simon Mardle will be consulted to clarify this comment. We will also consult him for suggestions on how to ensure optimality and if he thinks that we have reported any non-optimal solutions.*
The model is non-linear. This is simply due to the fact that the variables *total_vessels* and *average_vessel_days* are multiplied together. This makes solution and verification that the solution is optimal considerably more difficult than if the model was linear. A simple linearisation might be to make *average_vessel_days* constant and run the model for this variable between a range of values. MS Excel Solver could then be used in a linear form.	*We agree with this comment and Simon Mardle will be consulted on this issue.*
More flexibility could be incorporated in the model by allowing some variables to vary between bounds. Such variables include: CPUE (possibly in a more disaggregated form as discussed above) and crew share.	*We agree with this comment. This can easily be incorporated in the model if there is a wish by any interested parties to use the model for more detailed discussions.*
The "assume non-negativity" condition of Solver should be checked to restrict solution search to positive values only. Both vessels and days must be positive. This assists solution and applies to linear and non-linear versions.	*We agree with this comment and this issue will be addressed.*

The sensitivity of the model to small changes in key parameter values (in particular CPUE) should be evaluated and reported. The results should be interpreted in this context, where robustness in results is assured given reasonable tolerances.	*We agree and have attempted to address this issue. More comments could be made on the sensitivity of both CPUE and other key parameter values if requested by the profitability group.*
The model is a static view of the situation in the medium term. It does not include aspects of investment and change in prices/costs over time. Therefore, there is a high level of theoretical uncertainty to the model. However, this does not detract from the practicality of the model in the management setting for which it is developed.	*We agree with this comment and are content with this situation*
It may be that further questions could be answered using this approach, by simply modifying the objective under analysis. In this case it is maximising fleet size, but it could just as easily be maximising yield or employment for example.	*We will consult with industry and government to find out if they would be interested in us looking into this possibility.*